National Park Service
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Grand Canyon National Park

Response of Invertebrate Communities to Anthropogenic Activities

2015 Annual Report

ON THE COVER
Grand Canyon Black Tarantula
Photograph by: Matt Safford

Invertebrate Biodiversity Surveys in Grand Canyon National Park

2015 Annual Report

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Introduction

In 2008 a complete inventory of Grand Canyon macroinvertebrates was published, describing 1443 species in 497 genera and 176 families (Stevens 2008). Supplementing a 2005 invertebrate inventory, this report highlights the sheer number of invertebrate species found within Grand Canyon National Park (GRCA). As described in these inventories, extensive research has been done on invertebrates within certain taxonomic and geographic groups within GRCA (Stevens 2005, 2008). To date, a major focus has been on invertebrate species found along the Colorado River corridor. In the early 2000s, regular research and monitoring was done on the Kanab Ambersnail, an endangered subspecies found along the Colorado River (Sorensen 2005). Stevens has studied factors influencing the distribution of the chironomidae of the Colorado River within GRCA (1998). Usher (1987), Oberlin (1999), and others have focused on the aquatic invertebrates of tributary streams in GRCA.

This focus on invertebrates found along the Colorado River has left major gaps in the entomological knowledge of GRCA. A topic of interest is how the development of Grand Canyon Village, located on the South Rim, and the presence of over 5 million annual visitors, affects invertebrate biodiversity in the most heavily impacted area of GRCA.

In the area surrounding Grand Canyon Village, human activity has had a large influence on the composition and density of the pinyon-juniper forest of the South Rim. Extensive research has shown the close link between plants and invertebrates. Utilizing models of plant chemical defenses, population models of herbivorous insects, and food web theory, Price (1980) described how herbivorous insects hold a key role in the biodiversity of members of three trophic levels: plants, herbivorous insects, and insectivores. Studying the interactions between plants and herbivorous insects, Price (1980) found that as the number of plant species with specialized defenses increases, the number of species of both generalist and specialist insect herbivores increases. In turn, a higher number of herbivorous insect species leads to a higher number of vertebrate and invertebrate predator species. Di Giulio (2001) found that in agricultural areas, intensive management strategies led to lower invertebrate biodiversity and the dominance of generalist species. Studying the interactions between plants, insects, and predators is an important step for understanding how biotic communities evolve and are influenced by the macroinvertebrate communities present. Understanding how human impacts on forest ecology affect invertebrate biodiversity is an important consideration for conservation planning within the park.

The pinyon-juniper forest surrounding Grand Canyon Village can be categorized into three general categories: low anthropogenic impact, moderate anthropogenic impact, and high anthropogenic impact. The purpose of this project is to determine what impact these three land use strategies have on the biodiversity of invertebrates living in the area around Grand Canyon

Village. We hypothesize that as the amount of anthropogenic activity increases, invertebrate diversity will decrease as generalist invertebrates take advantage of the disturbance in plant communities.

2015 Project Objectives

1. Conduct invertebrate collections at nine survey sites in and around Grand Canyon Village.
2. Identify invertebrate specimens collected at each survey site to a family level.
3. Identify plants at each survey site to a species level.
4. Identify the anthropogenic impact at each survey site.

Study Area

GRCA is located within the Colorado Plateau physiographic province of the western United States. Located 124 km from Flagstaff, Arizona, Grand Canyon's landscape is dominated by the deep gorge cut by the Colorado River and the myriad of tributary canyons interspersed with buttes, benchlands, and mesas. The rim habitat is comprised of relatively flat forested plateaus often including ponderosa pine (*Pinus ponderosa*) and pinyon-juniper (*Pinus-Juniperus spp.*) woodlands. Elevations throughout the park range from 1,109 to 3,960 m. Total annual precipitation averages 17 cm per year, and temperatures range seasonally from below 0 to 40^0C (U.S. Weather Bureau, Climate and Precipitation Summaries, Arizona).

Invertebrate biodiversity surveys were conducted at nine select sites on the South Rim of Grand Canyon, near Grand Canyon Village, Arizona. All sites were within pinyon-juniper woodlands, and the elevation for these sites ranged from 2,001 to 2,153m .

Survey sites were divided into three land use categories. Three low anthropogenic impact (LAI) sites located in undisturbed pinyon-juniper forest outside Grand Canyon Village were used as controls. Three moderate anthropogenic impact (MAI) sites were established in areas of pinyon-juniper forest near Grand Canyon Village where prescribed burns and mulching has occurred. Three high anthropogenic impact (HAI) sites were established near human structures within Grand Canyon Village.

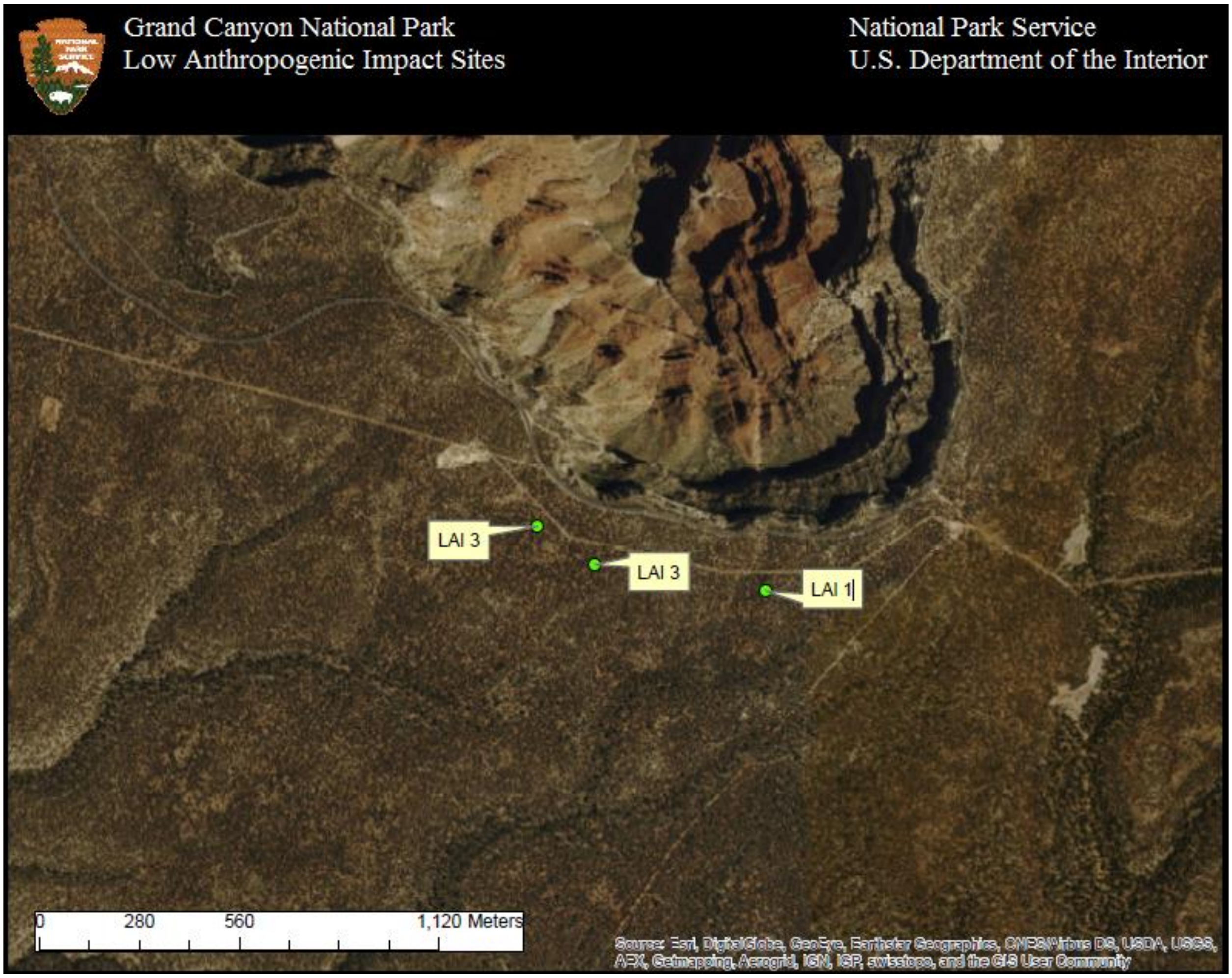

Figure 1. Location of the three low anthropogenic impact sites west of Grand Canyon village. Grand Canyon National Park, Arizona.

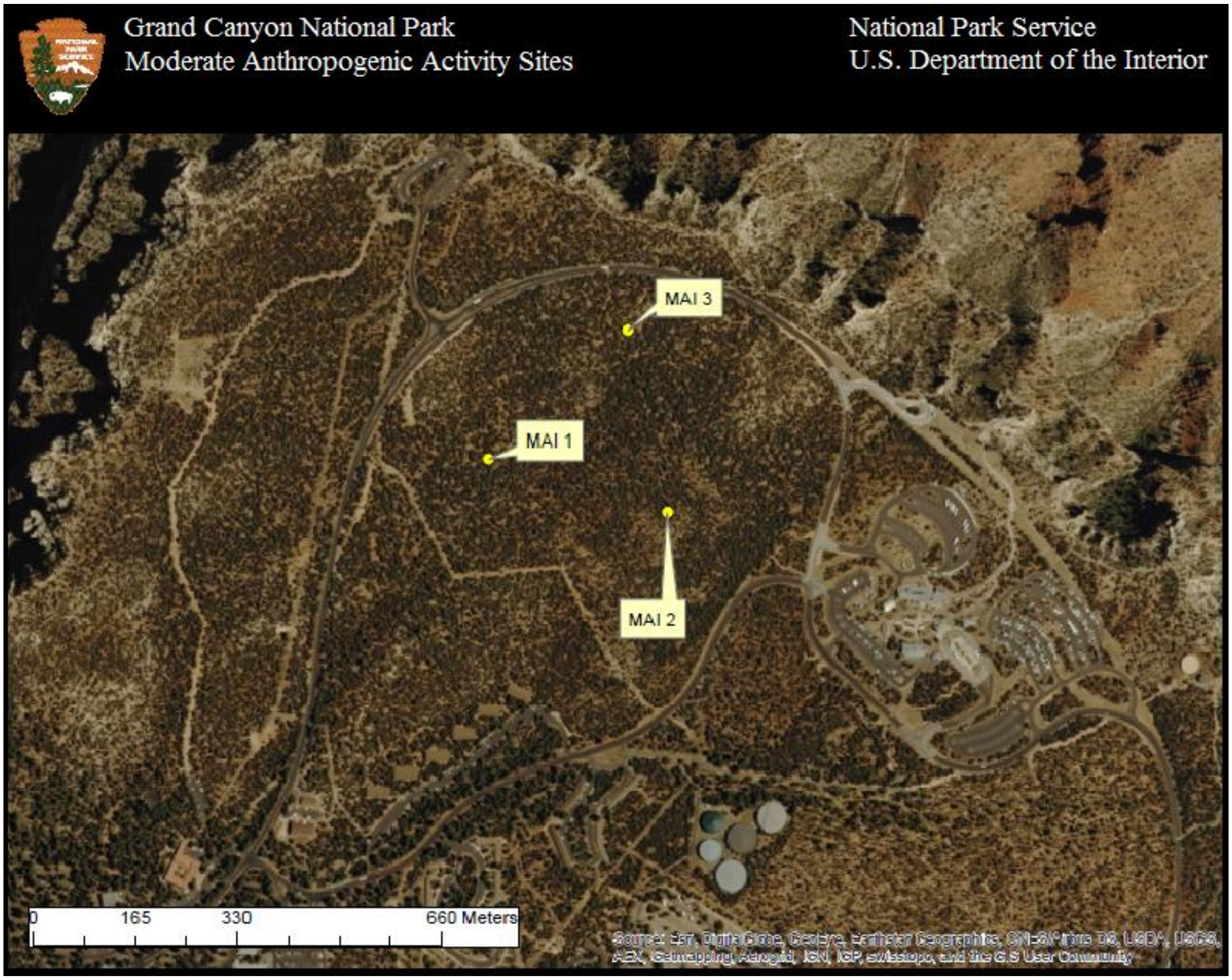

Figure 2. Location of the three moderate anthropogenic impact sites located between Grand Canyon Village and the Grand Canyon Visitor Center. Grand Canyon National Park, Arizona.

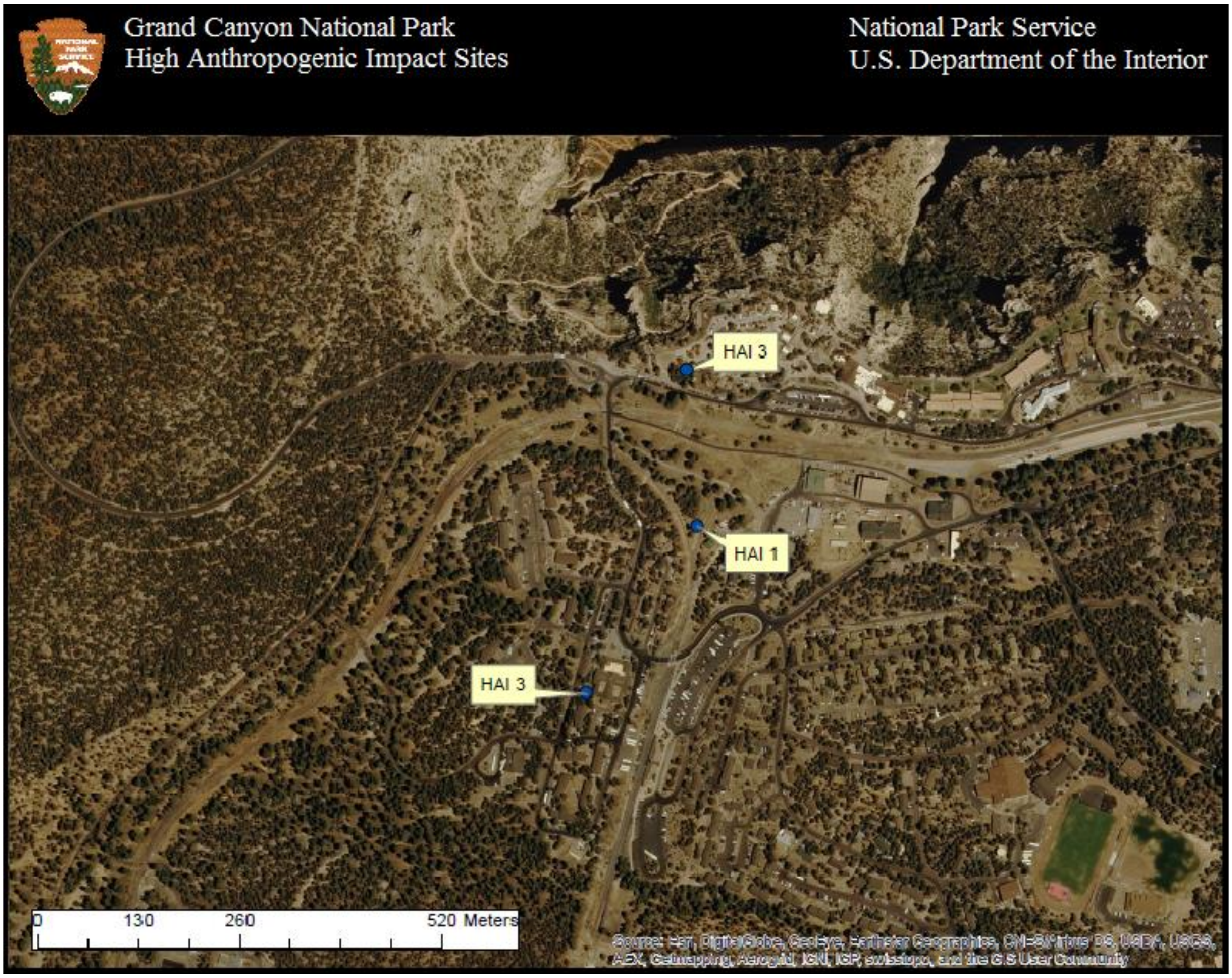

Figure 3. Location of the three high anthropogenic impact sites located within Grand Canyon village. Grand Canyon National Park, AZ

Methods

Using existing data and field surveys, areas in and around Grand Canyon Village that fell into each of the three land-use categories were documented. In ArcMap 10.2.2, polygons of potential research locations that fell into each land use category were created. Survey sites were randomly generated in each land-use polygon. Potential survey sites were ground truthed to ensure that the survey site was accessible, and its actual land use type matched the predicted land use type. To ensure that research was not conducted in biologically or culturally sensitive areas, the location of each survey site was cross checked with the GRCA Cultural and Vegetation Programs. Centered on each survey site, a 5m radius area was defined as the survey area for that site. To ensure that the number of insect and arachnid specimens collected was not biased by the dates of surveying, three sites (one from each land use category) were surveyed simultaneously. Each trio of sites was surveyed for seven to eight days. The three sites within each survey window were surveyed for the same period of time.

Each study area was surveyed in four ways: two methods of collecting invertebrate specimens, the identification of plants within the 5m radius study area, and the identification of anthropogenic impacts in the study area. The first method of invertebrate specimen collection was a barrier pitfall trap, which used a central barrier to divert invertebrates on the ground into a pair of pitfall traps, one on each end of the barrier. Mortality of reptiles and small mammals was prevented by having a low roof over the top of the trap (~1cm) and a cone in the mouth of the trap to prevent non-target species from entering. The euthanizing agent used in the pitfall traps was a 50/50 mix of "pet-safe" antifreeze (which uses propylene glycol instead of highly toxic ethylene glycol) and water. The second method of invertebrate specimen collection was a composite trap at each study site, used to collect flying insects. This style of trap combines elements of malaise traps, flight intercept traps, and pan traps, and is effective at collecting a high diversity of flying insects (Russo et al. 2011). Both traps were installed at each study site on day one of sampling, and removed on the final day of sampling.

Figure 4. Traps in place at site LAI 2. The composite trap is visible in the center of the photo, and the barrier pitfall trap is visible to the right of the photo.

The third field survey technique was identification of all plants within the 5m radius study area. Each plant within the study area was identified, and the percent ground cover of each plant species within the study area was document. Percent ground cover was defined as the area contained beneath the total foliage of each plant species. To reduce error, percent estimates were the average of estimates of at least two individuals.

The fourth field survey technique was the identification of anthropogenic disturbance within each study area. Anthropogenic impacts are defined as visually observable impacts of human activities, and include structures, soil alteration (e.g., tire tracks), impervious surfaces, and artificial pervious surfaces (e.g., gravel, mulch).

At the end of each sample period, invertebrate specimens were collected from four capture locations at each of the nine survey sites: the two pitfall traps on either end of the barrier, the capture basin at the bottom of the composite trap, and the capture container at the top of the composite trap. Specimens from all four capture locations were placed into a single storage container for transport to the GRCA Science and Resource Management Lab for identification.

Results and Discussion

The 2015 GRCA wildlife staff conducted 31 site visits to nine study sites in and around Grand Canyon Village.

Invertebrate Identification

All invertebrate specimen collection was completed between September 1st and September 24th, 2015. Sampling at sites LAI 1, MAI 1, and HAI 1 ran for eight days from September 1st to September 9th. Sampling at sites LAI 2, MAI 2, and HAI 2 ran for eight days from September 9th to September 17th. Sampling at sites LAI 3, MAI 3, and HAI 3 ran for seven days from September 17th to September 24th.

Because of limitations in time, equipment, and literature, specimens are being identified to a family level. For specimens that cannot be identified to the family level, order is used as a substitute for family. 17 specimens from 4 orders were not identified to a family level, primarily because of the extremely small size of these unidentifiable specimens. Invertebrates from 15 orders and 32 families have been identified.

Table 1. Number of invertebrate specimens identified from each of the nine sites, 2015. Grand Canyon National Park, Arizona.

Order	Family	LAI 1	LAI 2	LAI 3	MAI 1	MAI 2	MAI 3	HAI 1	HAI 2	HAI 3
Acari	Bdellidae	1	--	--	--	--	--	--	--	--
Araneae	Loxoscelidae	3	--	2	--	--	1	--	--	1
Araneae	Thomisidae	1	--	--	--	--	--	--	--	--
Coleoptera	Bostricidae	--	--	1	--	--	--	--	--	--
Coleoptera	Cantharidae	4	--	2	--	--	1	--	--	2
Coleoptera	Scotytidae	--	3	--	--	--	2	--	--	--
Coleoptera	Staphylinidae	3	--	--	1	--	4	--	--	1
Collembola	--	2	1	--	1	--	--	--	1	--
Diptera	Anthomyiidae	5	1	6	3	1	6	2	2	2
Diptera	Cecidomyiidae	1	--	2	4	3	2	1	12	1
Diptera	Chironomidae	3	5	4	--	--	3	--	3	1
Diptera	Culicidae	--	1	1	--	--	--	--	--	--
Diptera	Drosophilidae	--	--	--	--	--	1	--	1	--
Diptera	Muscidae	1	--	--	--	--	--	--	--	--
Diptera	Simuliidae	6	2	12	9	2	2	--	--	--
Hemiptera	Aphididae	--	--	--	--	--	--	3	1	--
Hemiptera	Cicadellidae	--	2	--	1	--	--	--	6	1
Hemiptera	Miridae	--	--	1	--	--	--	--	--	--
Hymenoptera	Ceraphronidae	--	--	2	2	1	1	--	--	1
Hymenoptera	Formicidea	--	3	2	--	3	--	6	--	1
Hymenoptera	Halictidae	--	--	--	--	--	--	--	1	--
Geophilomorpha	--		--	1	--	--	--	--	--	--
Lepidotera	Arctiidae	--	--	--	1	--	--	--	--	--
Lepidotera	Gelechiidae	--	--	1	--	--	1	--	--	1
Lepidotera	Noctunidae	2	--	--	--	1	--	--	--	--
Lepidotera	Tineidae	--	1	--	--	--	--	--	--	--
Lithobiomorpha	Henicopidae	--	--	--	--	--	--	--	3	2
Orthopetera	Rhaphidophoridae	2	--	5	--	1	--	3	--	1
Phthiraptera	Menoponidae	--	--	--	--	--	--	--	1	--
Psocoptera	--	1	--	1	1	1	3	--	1	2
Scorpiones	Buthidae	--	1	--	--	--	--	--	--	--
Thysanoptera	--	--	--	--	--	--	--	--	--	1
Total		34	20	43	23	13	27	15	32	18

Plant Identification

All plants within the 5m study area at each of the nine study sites were identified to a species level with help from GRCA Vegetation Program staff. Depending on time constraints, plants in each study area were identified either during the sampling period at that site, or at a later date. 44 species of vegetation have been identified in in the study areas- 33 native species, and 11 invasive species. All 11 invasive species were only found in areas of high anthropogenic impact.

Table 2. Plant species identified in the nine survey areas. Numbers represent the percent ground cover of each plant species, 2015. Grand Canyon National Park, Arizona.

Species	LAI 1	LAI 2	LAI 3	MAI 1	MAI 2	MAI 3	HAI 1	HAI 2	HAI 3
Arceuthobium divariucatum	--	1	1	--	--	--	--	--	--
Astragalus calycosus	1	--	--	1	--	1	--	1	--
Astragalus kentrophyta	1		1	1	1		1	1	
Astragalus oophorus	--	--	1	--	--	--	1	1	--
Bouteloua curtipendula	--	--	--	--	--	--	--	1	--
Bouteloua gracilis	--	6	--	--	4	10	--	5	3
Chamaebatiaria milleforlium	--	--	--	--	5	--	--	--	--
Cirsium nipponicum									1
Ericamerica mauseosa	--	--	--	--	--	--	6	--	2
Erodium cicutarium	--	--	--	--	--	--	1	--	2
Escobaria vivipara	1	1		1	1	--	--	--	--
Euphorbia palmeria	--	--	--	--	--	--	1	--	--
Gutierrezia Microcephela	--	--	--	--	--	2	2	2	--
Gutierrezia sarothrae	--	1	--	--	--	--	1	--	--
Hordeum jubatum	--	--	--	--	--	--	--	1	2
Ipomopsis arizonica	--	--	--	--	1	--	--	--	--
Junipers communis	--	--	--	--	--	--	4	--	1
Juniperus osteosperma	12	--	15	8	10	--	--	25	12
Machaeranthera canescens	--	--	--	--	--	--	1	2	--
Marrubium vulgare	--	--	--	--	--	--	1	--	--
Medicago lupulina	--	--	--	--	--	--	--	1	--
Melilotus officinalis	--	--	--	--	--	--	--	2	--
Opuntia engelmannii	--	--	--	--	1	1	5	--	--
Penstamen linarioides	1	--	--	--	--	1	--	--	--
Penstemon Pacyphylus	--	--	--	1	1	1	--	--	--
Penstemon Utahensis	--	1	--	1	1	--	--	--	2
Phoradendron juniperinum	1	--	--	--	--	--	--	1	1
Pinus edulis	30	25	60	10	5	13	2	15	22
Pinus ponderosa	--	--	--	--	--	--	2	12	--
Poa fendleriana	11	10	20	2	1	2	2	10	5
Portulaca oleracea	--	--	--	--	--	--	1	--	1

Purshia Mexicana	15	8	--	--	--	6	--	--	--
Ribes cereum	--	--	--	--	--	--	--	--	1
Ribes velutinum	--	--	--	--	--	--	2	1	2
Salvia aethiopis	--	--	--	--	--	--	1	--	--
Sphaeralcea ambigua	--	--	--	--	--	--	2	1	--
Sporobolus cryptandrus	--	--	--	--	--	--	4	--	--
Symphoricarpos rotundifolius	--	--	--	--	1	--	2	2	1
Taraxacum officinale	--	--	--	--	--	--	--	--	1
Thlaspi arvense	--	--	--	--	--	--	1	1	--
Townsendia nuttalli	--	1	--	--	--	--	--	--	--
Unknown Invasive	--	--	--	--	--	--	--	--	--
Yucca baccata	--	--	2	--	2	5	--	--	--

Anthropogenic Disturbance

Anthropogenic disturbance is defined as all observable human disturbances within a plot, including artificial pervious surfaces (gravel, mulch), impervious surfaces (structures, pavement), soil disturbance, burn evidence, and cut timber. The three LAI sites had no observable anthropogenic disturbance. The dominant category of disturbance in MAI and HAI sites were artificial pervious surfaces. Impervious surfaces were found only in the HAI sites.

Table 3. Anthropogenic disturbance in the nine survey areas, measured as a percent of the surface area of each study area altered by each type of disturbance, 2015. Grand Canyon National Park, Arizona.

Impact Type	LAI 1	LAI 2	LAI 3	MAI 1	MAI 2	MAI 3	HAI 1	HAI 2	HAI 3
Structure	--	--	--	--	--	--	--	25	--
Impervious Surface	--	--	--	--	--	--	2	30	--
Pervious Surface	--	--	--	90	85	80	40	5	60
Controlled Burn Evidence	--	--	--	--	--	--	--	--	--
Soil Disturbance	--	--	--	5	--	--	--	10	--
Cut Timber	--	--	--	3	2	1	1	--	--
Misc	--	--	--	--	--	--	2	--	1
Percent of Ground Disturbed	0	0	0	98	87	81	45	70	61

Invertebrate Biodiversity

Data analysis is currently being conducted using the software program R, version 3.2.4. Invertebrate diversity at each site was calculated using Shannon's diversity index. This index was chosen based on its use in previous studies of anthropogenic impacts on invertebrate diversity (Di Guilio 2001). As anthropogenic activity increased, invertebrate diversity decreased. In low anthropogenic impact sites the diversity was consistently high, while site diversity varied from high to low in the moderate and high anthropogenic activity sites. This analysis confirms the first portion of the hypothesis, that invertebrate diversity would decrease as anthropogenic activities increase, but does not confirm the second portion of the hypothesis, which states that this decrease in diversity would be caused by generalist invertebrates taking advantage of the disturbance in plant communities.

Table 4. Invertebrate diversity in the nine survey areas, calculated using Shannon's diversity index, 2015. Grand Canyon National Park, Arizona.

Site	Diversity Index	Average Diversity for each Land Use Category
LAI 1	2.45851	2.30803
LAI 2	2.12516	2.30803
LAI 3	2.340426	2.30803
MAI 1	1.831045	2.02547
MAI 2	1.95126	2.02547
MAI 3	2.294122	2.02547
HAI 1	1.495482	2.00755
HAI 2	1.94863	2.00755
HAI 3	2.582306	2.00755

Following identification of invertebrate biodiversity at each site, linear fit models were created to assess which factor had the largest impact on invertebrate biodiversity. Three variables tested were the ground cover of invasive plants in each plot, ground cover of native plants in each plot, and anthropogenic disturbance in each plot. The first two variables appeared to have a negligible impact on invertebrate biodiversity. The third variable, anthropogenic disturbance, shows a larger correlation with changes in invertebrate diversity.

To further assess which factor best explains the change in diversity between land use types, the Akaike Information Criteria (AIC) was used. AIC is a method of selecting the highest quality model from a set of models. The AIC compared the quality of the three models, in addition to a forth model, which categorized the 9 study sites into 2 categories: No anthropogenic impact (all LAI), and any anthropogenic impact (all MAI & HAI sites). AIC prefers this model because using two variables (No anthropogenic impact and Any anthropogenic impact) it explains the same amount of deviance as models using three variables (LAI, MAI, HAI). This seems to indicate that changes in invertebrate diversity do not happen along a gradient, and that diversity remains high until a certain threshold of anthropogenic impact is reached, at which point the invertebrate diversity falls rapidly.

Recommendations

Continued Statistical Analysis

Use of Shannon's diversity index has confirmed the hypothesis that invertebrate diversity decreases as anthropogenic activity increases. Additional analysis is needed to confirm that anthropogenic ground disturbance, rather than other variables such as native or invasive plant ground cover, has the largest impact on invertebrate diversity. If this is confirmed, further analysis will attempt to identify which category of anthropogenic impact has the largest impact on diversity.

Future Research

Given the lack of research into how anthropogenic activities affect invertebrate biodiversity in GRCA, it will be important to conduct future research on this topic. Time constraints mean that the current sample sizes are small. An important step will be to continue the current analysis of invertebrate biodiversity in the three land-use categories identified, creating a larger body of knowledge that can be used for future analysis. The continuation should consist of two parts. First, future research should increase the number of sampling periods throughout a year. Because of the short life span of many invertebrates, the current sample protocol of three one-week samplings in the fall captures only some of the invertebrates that live at each sample site, and ignores species that are active in an adult phase at different times of the year. Sampling during the spring and summer would increase the number of species captured, and would help assess the populations and distributions of many species of short-lived invertebrates. Second, the number of sample sites should be increased. The current model of three sample sites in each land use category is a small sample size that may over- or underestimate the population sizes of plant species living in each land use category. Increasing the number of sample sites may also reveal additional plant species present in each land use category.

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